

Bio-Inspired Computation: Success and Challenges of IJBIC

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Abstract

It is now five years since the launch of the International Journal of Bio-Inspired Computation (IJBIC). At the same time, significant new progress has been made in the area of bio-inspired computation. This review paper summarizes the success and achievements of IJBIC in the past five years, and also highlights the challenges and key issues for further research.

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1 Introduction

Bio-inspired computation, especially those based on swarm intelligence, has been in rapid developments in the last two decades [Kennedy and Eberhart(1995), Yang(2008), Cui and Cai(2009), Cui et al.(2010), Yang et al.(2013), Gandomi et al.(2013a)]. The literature has been expanding significantly with diverse applications in almost all area of science, engineering and industries [Yang and Koziel(2010), Yang et al.(2013)].

The launch of the IJBIC in 2009 was a significant step to provide a timely platform for researchers to exchange ideas in bio-inspired computation. Initially, it aimed to publish quarterly, 4 issues per year. One year later in 2010, the journal had to expand to 6 issues a year, due to the overwhelming number of submissions and interests generated in the research communities. Since then, it becomes a steady inflow of high quality submissions with bimonthly publications. In 2012, IJBIC was included by Thomson Reuters in their Science Citation Index (SCI) Expanded, and the first impact factor 1.35 was announced earlier in 2013. In the short 5 years, IJBIC has achieved its goals successfully.

Many other journals such as Soft Computing, Swarm Intelligence, IEEE Transaction on Evolutionary Computation, Neural Computing and Applications, and Heuristics all can include bio-inspired computation as a topic; however, IJBIC was the only journal that specifically focused on bio-inspired computation. It is no surprise that IJBIC has become successfully in such a short period.

Bio-inspired computation (BIC) belongs to the more general nature-inspired computation [Yang(2008)], and BIC includes swarm intelligence (SI) as its subset. The algorithms that are based on swarm intelligence are among the most popular algorithms for optimisation, computational intelligence and data mining [Yang et al.(2013)]. These SI-based algorithms include ant colony optimisation, bee algorithms such as artificial bee colony, bat algorithm, cuckoo search, firefly algorithm, particle swarm optimization and others. In fact, significant progress has been made in the last twenties years, and the publications in IJBIC just provides a good snapshot of the latest developments.

The aim of this paper is two folds: to summarize the successful developments in IJBIC and to highlight the trends and key issues concerning bio-inspired computation. Therefore, this paper is organized as follows. Section 2 summarizes the latest developments concerning bio-inspired computation, while Section 3 discusses the current trends. Section 4 highlights the challenges and key

issues in bio-inspired computation. Finally, Section 5 concludes briefly with some topics for further research.

2 Recent Developments in Bio-Inspired Computation

The inaugural issue kicks off with the first paper by [Gross and Dorigo(2009)] about swarms of robots for group transport, followed by studies on particle swarm and other methods. Then, [Deb(2009)] discussed the alternatives to machine vision. Since then, the scopes and aims of IJBIC has expanded significantly, and the studies published in the journal can be summarized into two main categories: algorithm developments and applications.

2.1 Algorithm Developments

In terms of algorithm developments, there are three strands: the developments of new algorithms, improvements of existing algorithms, and the analysis of algorithms. Due to the complexity of the problems in bio-inspired computation, it is not practical to systematically analyze all relevant research in detail. In stead, we will briefly touch relevant studies and highlight the most relevant progress in all three areas. In addition, it is not possible to include all the papers published in the last five years in IJBIC, and thus we only sample a fraction (e.g., about a quarter or more research papers) so as to provide a timely snapshot of the diversity and depth of the current research and developments.

Among the development of new algorithms published in IJBIC, [Yang(2010)] introduced the new firefly algorithm and some stochastic functions, which is the most cited paper of IJBIC with a total number of 151 citations in last 3 years since its publication in 2010. Later [Yang(2011b)] extended the bat algorithm for single objective optimisation to solve multiobjective optimisation problems. In fact, the firefly algorithm represents a successful algorithm with diverse applications [Fister et al.(2013a), Yang(2013), Fister et al.(2013b), Srivastava et al.(2013), Gandomi et al.(2013b)].

In addition, [Adamatzky(2012)] introduced a new idea using slime mould to compute planar shapes, which mimics important features of shortest paths in route systems such as highways. Furthermore, [Shah-Hosseini(2009)] presented an intelligent water drops (IWD) algorithm, though strictly speaking, IDW is not a bio-inspired algorithm, however, it does has some characteristics of swarm intelligence.

On the other hand, [Ray and Mondal(2011)] used DNA computing to carry similarity-based fuzzy reasoning, while [Saha et al.(2013)] introduced the bacteria foraging algorithm to solve optimal FIR filter design problems. In addition, [Cui et al.(2013)] proposed the artificial plant optimisation algorithm with detailed case studies, especially [Cai et al.(2012)] carried light responsive curve selection for photosynthesis operator of artificial plant optimisation algorithm.

In addition to algorithm developments, more research activities have focused on the improvements of existing algorithms. For example, [Neri and Caponio(2010)] introduced a variant of differential evolution for optimisation in noisy environments, while [Pandi et al.(2010)] introduced the modified harmony search for solving dynamic economic load dispatch problems. At the same time, [Xie et al.(2010)] provided a brief survey of artificial physics optimisation, while [Roy et al.(2010)] used differential harmony search algorithm to design a fractional-order PID controller.

Furthermore, [Pal et al.(2011)] used a modified invasive weed optimisation algorithm to carry out linear antenna array synthesis, while [Layeb(2011)] improved the cuckoo search algorithm by introducing a novel quantum inspired cuckoo search to solve knapsack problems. On the other hand, [Yang and Deb(2012)] combined the eagle strategy with differential evolution to produce a new hybrid, and [Jamil and Zepernick(2013)] extended cuckoo search to study multimodal function optimisation.

Theoretical analysis in contrast is relatively weak in IJBIC, which is also true for most other journals in the whole area. However, some papers can be classified or partly classified as theoretical analyses because they intended to address the theoretical and mathematical aspects of recent algorithms. For example, [Yang(2011a)] provide an analysis about random walks and its role in

nature-inspired metaheuristic algorithms, while [Xiao and Chen(2013)] discussed relationships between swarm intelligence and artificial immune system. In addition, [Green(2011)] discussed the elements of a network theory of adaptive complex systems, while [Komatsu and Namatame(2011)] investigated the dynamic diffusion in evolutionary optimised networks.

The lack of theoretical studies suggests that it is highly needed to address many problems in the near future, and we hope that this paper can inspire more research in this area.

2.2 Applications

Applications are very diverse and form by far the vast majority of the research papers published in IJBIC. In fact, more than two thirds of all the studies are about applications of bio-inspired algorithms. Such diversity is one of key reasons that drive the success of the journal and may inspire more applications. The expanding literature makes it unrealistic to analyze or even list all the papers in applications published in the last five years. Therefore, we only select a fraction of the papers and try to provide a representative subset of the current activities in bio-inspired computation.

For example, [Arumugam et al.(2009)] carried out the optimal control of the steel annealing processes by PSO, while [Sivanandam and Visalakshi(2009)] presented a study in dynamic task scheduling with load balancing using parallel orthogonal particle swarm optimisation. In addition, [Khabbazi et al.(2009)] used the imperialist competitive algorithm for minimising bit error rates, and [Singh et al.(2010)] studied the damping of low frequency oscillations in power system network using swarm intelligence tuned a fuzzy controller, while [Zhang and Cai(2010)] used a hybrid PSO to study economic dispatch problems.

Furthermore, [Yampolskiy(2010)] applied bio-inspired algorithm to the problem of integer factorisation, while [Sheta(2010)] designed analogue filters using differential evolution. Then, [Laalaoui and Drias(2010)] used an ACO approach with learning to solve preemptive scheduling tasks.

On the other hand, [Bonyadi and Shah-Hosseini(2010)] used a dynamic max-min ant system to solve the travelling salesman problem, and [Bessedik et al.(2011)] investigated graph colouring using bees-based algorithm.

A few special issues have been edited to address a subset of active and special research topics. For example, [Tanimoto(2011)] edited a special issue on evolving world: games, complex networks, and agent simulations. In addition, [Liu and Zhang(2012)] edited a special issue on computational intelligence and its applications in engineering, and [Natarajan et al.(2012)] carried out a comparative study of cuckoo search and bat algorithm for bloom filter optimisation in spam filtering. In terms of the summaries of more recent developments, [Yang(2012)] edited a special issue on metaheuristics and swarm intelligence in engineering and industry, where [Marichelvam(2012)] presented an improved hybrid cuckoo search for solving permutation flow shop scheduling problems.

The diversity of the applications can be seen from a wide range of topics concerning applications. [Handa(2012)] used neuroevolution with manifold learning for playing Mario, while [Srivastava et al.(2012a)] solved test sequence optimisation using cuckoo search, and later [Srivastava et al.(2012b)] used an approach based on cuckoo search to estimate software test effort. Furthermore, [Sing et al.(2013)] used artificial bee colony algorithm to optimise coordination of electro-mechanical-based overcurrent relays. In the area of image processing, [Dey et al.(2013)] used cuckoo search to optimise the scaling factors in electrocardiogram signal watermarking.

In the area of web service and networks, bio-inspired modelling of distributed network attacks was studied by [Solgueiro and Abreu(2013)], and [Chifu et al.(2013)] optimized the semantic web service by bio-inspired methods.

Multiobjective optimization has also been addressed. For example, [Zeng et al.(2013)] used non-dominated sorting genetic algorithm to solve constrained optimisation problems, while [Yang(2011b)] presents a multiobjective extension to the bat algorithm.

Obviously, there are many other application topics, and interested readers can look at the table of contents of IJBIC for details.

3 Recent Trends

The rapid developments in bio-inspired computation mean that it is difficult to predict its trends, though the current research activities may provide, to a certain extent, a good indication of what may happen next.

There is no single paper that can represent the current trends, though review papers tend to summarize more comprehensively what topics and applications have been addressed in recent studies. In this sense, review papers may provide a more comprehensive starting point. For example, [Akerkar and Sajja(2009)] provided a relatively comprehensive review on bio-inspired computing, while [Yang(2011a)] provided an insightful analysis of randomization techniques in nature-inspired algorithms. In addition, [Parpinelli and Lopes(2011)] surveyed new inspirations in swarm intelligence, and [Yang and He(2013)] reviewed the bat algorithm comprehensively with detailed literature about various applications.

So what are the trends (you may wonder)? In fact, this is a very difficult question to answer, and we do not wish to mislead. Therefore, our comments below act as an optional, personal notes, rather than an answer to this challenging questions. From our observations and the analysis of the table of contents of IJBIC, we may summarize the current trends as follows:

- Complex, real-world applications. More and more studies have focussed on real-world applications such as highly nonlinear design problems in engineering and industry. These applications tends to be complex with diverse and stringent constraints, and thus the problems can typically be multimodal.
- Data intensive applications: the data volumes are increasing dramatically, driven by the information technology and social networks. Thus, data intensive data mining techniques tend to combine with bio-inspired algorithms such as PSO, cuckoo search and firefly algorithm to carry out fault detection and filtering as well as image processing.
- Computationally expensive methods: Even with the best optimisation algorithms, the computational costs are usually caused by the high expense of evaluating objective functions, often in terms of external finite element or finite volume solvers, as those in aerospace and electromagnetic engineering. Therefore, approximate methods to save computational costs in function evaluations are needed.
- Network and systems: Many research activities also focused on applications to complex networks and systems, including computer networks, electricity/energy networks, supply chain networks, and biological/ecological systems as well as social networks.
- Novel applications: Sometimes, the existing methods and also new algorithms can be applied to study very new problems. Such novel applications can help to solve interesting and real-world problems. For example, bio-inspired algorithms can often be combined with traditional approaches to carry out classifications, feature selection and even combinatorial optimization such as the travelling salesman problem.

Obviously, as we mentioned earlier, there are other trends as well. Developments of new hybrid algorithms and continuing improvements of existing algorithms form a constant trend in the last twenty years. The above few points are just the parts that we hope researchers will continue to spend more time on, because these applications are important topics that will have a huge impact in real-world applications.

4 Challenges and Key Issues

Despite the success in bio-inspired computation, many challenging problems remain unsolved. Though different researchers may think differently in terms of the challenging problems, however, we will highlight a few areas that further research and progress will be more likely to have a huge impact.

- Theoretical analysis: Despite the rapid developments in applications, theoretical analysis still lacks behind. Any theoretical analysis will help to gain insight into the working mechanisms of bio-inspired algorithms, and certainly results concerning stability and convergence are useful. However, many algorithms still remain to be analyzed by mathematical tools. Future research efforts should focus more on the theoretical analysis.
- Large scale problems: The applications in IJBIC are diverse, however, the vast majority of the application papers have dealt with small or moderate scale problems. The number of design variables are typically less than a hundred. As real-world applications are large scale with thousands or even millions of design variables, researchers should address complex large-scale problems to test the scalability of optimisation algorithms and to produce truly useful results.
- Combinatorial problems: Among complex optimisation problems, combinatorial optimization is typically hard to solve. In fact, most combinatorial problems do not usually have good methods to tackle with. In many cases, nature-inspired metaheuristic algorithms such as ant colony optimisation (ACO) and cuckoo search can be a good alternative. In fact, ACO, firefly algorithm and cuckoo search have all been applied to study the travelling salesman problem with good results. In reality, combinatorial problems can be from very different areas and applications, more research is highly needed.
- True intelligence in algorithms: As the significant developments expand in bio-inspired computation, some researchers may refer to some algorithms as ‘intelligent algorithm’. However, care should be taken when interpreting the meaning. Despite the names, algorithms are not truly intelligent at the moment. Some algorithms with fine-tuned performance and integration with expert systems may seem to show some low-level, basic intelligence, but they are far from truly intelligent. In fact, truly intelligent algorithms are yet to be developed.

Obviously, there are other important open problems, and some start to emerge with interesting ideas. For example, all algorithms have some parameters, and the tuning of these parameters is important to the performance of an algorithm. There is no easy way to tune an algorithm properly. A novel framework for self-tuning algorithms has been proposed by [Yang et al.(2013)], which can tune an algorithm automatically.

5 Concluding Remarks

The rapid developments of bio-inspired computation can be reflected in the progress of the Inter-science journal: IJBIC in the last five year. Despite the short history, IJBIC has achieved successfully its main aim as a platform for exchanging research and ideas in bio-inspired computation. The diverse applications indicated the activeness and hotness of the topics, while the rarity in some topics such as theoretical results also poses further challenges for the journal.

From our observations and experience, we suggest the follow topics for further research and welcome more papers in IJBIC:

- Theoretical analysis of bio-inspired algorithms.
- Large-scale, real-world applications.
- Combinatorial optimisation.
- Data mining and image processing.
- Novel applications.

This review paper celebrates the five year achievements of this journal and also highlights the future challenges and key issues. There is no doubt that IJBIC will continue its success with greater achievements in the coming years. It is hoped that this paper can inspire more research in both theory and applications in the future.

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